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Case Series

Correlation between onset of ACL injury and incidence of articular cartilage and meniscal injuries

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ABSTRACT

Background: Delayed anterior cruciate ligament (ACL) reconstruction surgery may increase the risk of chondral and meniscal injuries but the time interval between injury and surgery is not fully determined and the effect of ACL-deficiency rotational instability may vary among different zones of knee articular cartilage. Purpose To study chondral injuries in ACL-deficiency patients in different articular zones and various durations between ACL injury and reconstruction.

Study Design: Case series – prospective observational study.

Materials and Methods: Prospective observational study of 212 cases (197 male and 15 female) with specific age group (16-44 years) having ACL injury and managed by arthroscopic ACL reconstruction, articular cartilage injury rate and severity (based on ICRS classification) was assessed in 5 zones of knee articular cartilage and correlated with different durations between injury and surgery as well as correlation with concomitant meniscal injuries.

Results: Medial tibia was the most common zone of chondral injury in ACL-deficiency knee (54.2%) while patella was the least common zone (28.8%), severe chondral injuries rate increased from (3%) in patients who were operated within 6 months to (11.1%) in patients of 6-12 months group and higher with longer duration reaching to (63.6%) when ACLR was delayed more than 4 years from injury. Concomitant meniscal injuries were associated with higher rate of severe chondral injuries (20.4%) than cases without meniscal tear (4%), medial meniscal tears were more common (65%) than lateral tears (23.3%) while both menisci were observed in (11.7%), complex meniscal tear was the most common pattern (33.7%) on medial side.

Conclusion: Delaying ACL reconstruction surgery will increase frequency of chondral injuries, severe chondral injuries rate is increased after 6 months in medial side and after 2 years on lateral side, concomitant meniscal injury is associated with higher rate of severe chondral lesions.

1. Introduction

Among athletes, the most common knee injury is Anterior Cruciate Ligament (ACL) injury[1] affecting mainly athletes between 15 to 45 years of age,[2] ACL injury may occur as a sole event (isolated ACL rupture) or associated with meniscal, chondral or other ligaments injuries with incidence of (36.4%) medial meniscal injury and (15%) chondral injury.[3]

Even in an isolated ACL rupture; anteroposterior and rotatory knee instability may lead to more mechanical pressure on menisci and articular cartilage leading to damage over time,[4] meniscal lesions are significant as studies have described the role of meniscus in shock absorption and articular cartilage protection, this explains the higher incidence of knee arthrosis after ACL

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reconstruction in absent meniscus.[5]

Conservative treatment of ACL rupture may lead to meniscal and chondral lesions because of increased shear force but not all chondral lesions lead to osteoarthritis changes,[6] deeper and larger chondral defects have higher risk of developing OA because of subsequent articular surface overloading.[7]

ACL Reconstruction (ACLR) has been increasing[8] and became the most effective way to regain knee stability in ACL-deficient knees,[9] hamstring and patellar tendons were used successfully as autogenous grafts but there is no adequate evidence about the best time to reconstruct ACL to avoid meniscal and chondral damage.[10]

Too early ACLR has been associated with high risk of arthrofibrosis and infection,[11] as well as suppressing the self-healing process in some patients with ACL injuries which have endogenous regeneration potential to some degree[12] and possible "coping" ability with nonoperative management, for that reason, most of surgeons are waiting for acute hemarthrosis resolution, knee edema to be subsided, normal gait and range of movement restoration, better quadriceps function to improve post-operative outcome.[13]

On the other hand, delayed ACLR carries higher risk for meniscal pathology from recurrent episodes of instability which could result in subsequent damage to articular surface, while delaying ACLR more than 1 year increases the incidence of osteoarthritis.[14]

In 1961, Outerbridge published his first article concerning grading of chondral injuries as he studied 196 cases of medial meniscectomy, it is one of the most widely accepted and used classifications, he graded the softening and swelling of the cartilage in chondromalacia patella as grade 1, while grade 2 is for fibrillation and fissuring in area less than half inch, grade 3 is the same as grade 2 but with an area larger than half inch, when the cartilage is eroded down to bone; it is regarded as grade 4.[15]

In 2003, a new classification system was developed by International Cartilage Repair Society (ICRS) depends on the lesion depth and the area of damage, macroscopically normal cartilage without a defect is classified as ICRS 0 (normal), if the cartilage has a superficial lesion is classified as ICRS 1 (nearly normal); fibrillation or softening is ICRS 1a while superficial laceration is classified as ICRS 1b, deeper lesion but less than 50% of cartilage thickness is classified as ICRS 2 (abnormal), lesions extending more than 50% of cartilage thickness are classified as ICRS 3 (severely abnormal); there are 4 subgroups for these lesions depending on the depth and the pattern of the lesion; ICRS 3a is for lesion extending >50% of thickness but not reaching the calcified layer, while ICRS 3b is for lesion reaching to calcified layer but not to subchondral bone, ICRS 3c is for lesions reaching subchondral bone but not through it, while ICRS 3d is for blisters, when the lesion is extending through the subchondral bone; it's graded as ICRS 4 (osteochondral defect).[16]

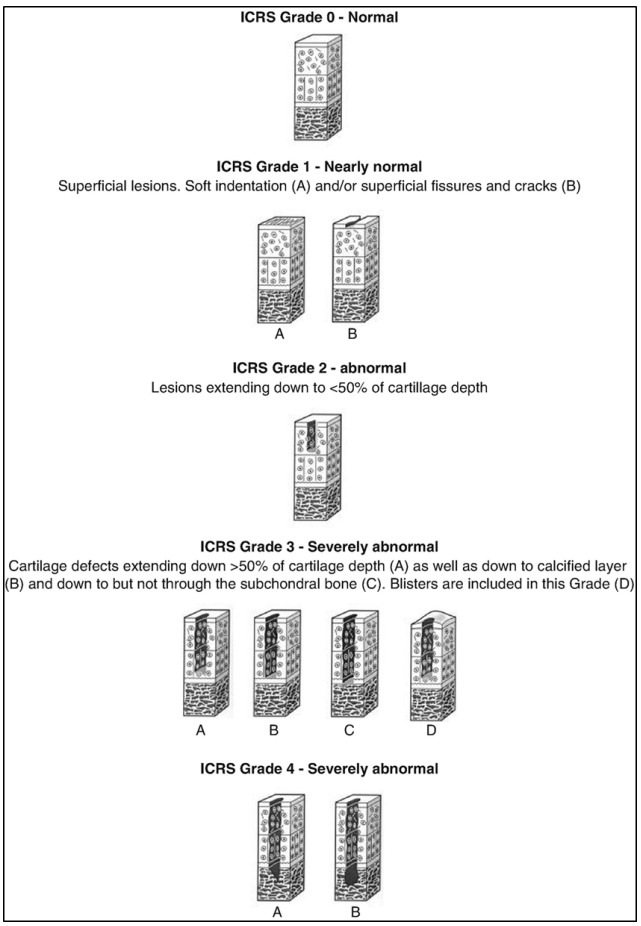

Fig. 1: ICRS classification of chondral injuries[16]

2. Study Aim

To study the rate, severity and location of chondral injuries in patients with anterior cruciate ligament injury with various time intervals between injury and reconstruction from less than 6 months till more than 4 years.

3. Materials and Methods

3.1. Study design

A prospective quantitative case series study on 212 patients having ACL injury and undergoing ACL reconstruction surgery in Tuymalik hospital from May 2017 till June 2020, knee articular surface was divided into 5 zones (medial tibia, medial femur, lateral tibia, lateral femur and patella) and patients were grouped into 6 groups according to the duration between ACL injury & surgery (less than 6 months, 6-12 months, 1-2 years, 2-3 years, 3-4 years and more

than 4 years), chondral injuries were assessed, localized (5 articular zones), graded (according to ICRS) and correlated with duration (6 time interval groups) to assess the effect of ACL deficiency instability on chondral damage.

3.2. Inclusion criteria

1. Both genders with age group of (16-44) years.
2. Suggestive history of knee instability symptoms (giving way or inability to play sport).
3. Positive signs of knee anterior or anterolateral rotatory instability (Anterior Drawer test, Lachman test or Pivot Shift test).
4. MRI signs of ACL incompetency (rupture or absent ACL).

3.3. Exclusion criteria

1. Fractures in distal femur, tibial plateau or patella (both extra-articular and intra-articular fractures).
2. Multi-ligament knee injury (concomitant other ligament rupture with ACL injury)
3. Any deformity altering anatomical or mechanical axes of lower limb.
4. Previous knee surgery on the affected site (open or arthroscopic).
5. Osteoarthritic changes (seen by radiography).
6. Body Mass Index higher than 30.
7. Hip-spine disease.
8. Heavy worker (patients with knee overload)
9. Missing information (patients who do not recall the exact date of injury).

3.4. Data collection

Patients were interviewed personally and pre-operative part (demographic data and exclusion criteria) of our questionnaire was filled to help in recruitment and selection of patients to be included in this study, the other part of intra-operative finding was filled post-operatively

3.5. Pre-operative evaluation

3.5.1. Proper history

All patients were asked about their knee complaint, any activity-related instability, exact date of trauma, mechanism of injury and pre-injury knee problem or surgery.

3.5.2. Clinical examination

Thorough knee examination was performed including knee anterior instability tests as Anterior Drawer, Lachman and Pivot Shift; patients with knee pain or locking may have false negative tests, but they still were included in the study.

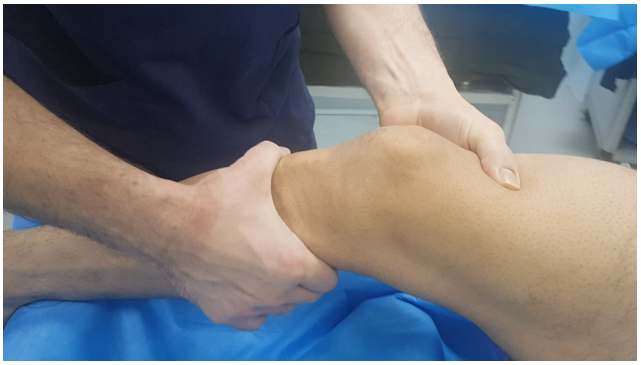

Fig. 2: One of our cases being assessed for anterior knee instability by Lachman test

3.5.3. Laboratory tests

Routine per-operative investigations were ordered including complete blood count (CBC), viral screen and other related tests according to patient health status.

3.5.4. Radiography

knee radiography with (AP & Lateral views) was taken and other related views according to patient's clinical evaluation to assess for radiographic suggestive signs of ACL as Segond fractures or to exclude underlying cause of knee symptoms rather than ACL injury.

3.5.5. Imaging

All patients with suggestive history and clinical examinations were asked to perform MRI scan of affected knee to assess ACL competency, bone bruise, concomitant ligament or meniscal injuries or to exclude other pathologies.

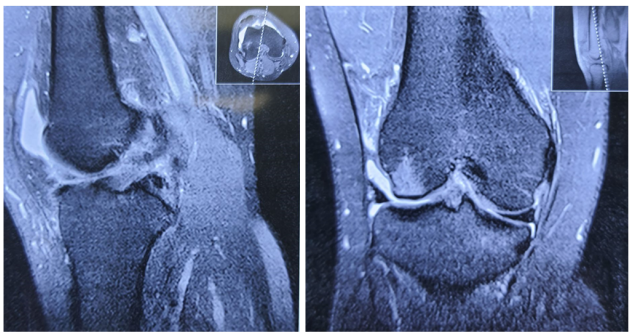

Fig. 3: One of our cases with ACL rupture and bone bruise in lateral femoral condyle shown on MRI T2 weighted image

3.5.6. Intra-operative Assessment

A check scope was performed prior to ACL reconstruction for all patients; confirming the ACL incompetency and assessing associated intra-articular pathology as chondral and meniscal injuries.

ACL rupture was grouped into either complete rupture or partial tear, then complete ruptures were sub-grouped into either proximal avulsion (within 5 mm from femoral attachment) or mid-substance tears, if ACL could not be visualized; it was regarded as complete rupture with absent ACL.

Chondral and meniscal injuries were graded by direct visualization (no chondral MRI grading was considered as we lack high-resolution MRI images), chondral injury site (articular surface zone) and depth (graded by ICRS classification) were recorded.

ICRS Grades 1 and 2 were considered mild while grades 3 and 4 were regarded as severe chondral injuries.

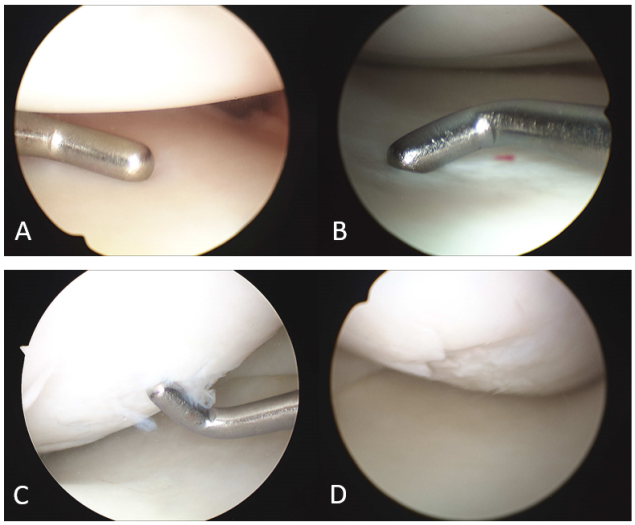

Fig. 4: Arthroscopic images for some of our patients with mild chondral injuries, **A)**: grade 0 "Normal", **B)**: grade 1A "Softening", **C)**: grade 1B "Fibrillation", **D)**: grade 2 "less than 50% loss of cartilage" Fibrillation"

3.6. Data analysis

SPSS (version 22) software was used in this study, two approaches were used for statistical analysis; descriptive and analytic approaches.

Descriptive approach for calculating frequencies, percentages, mean ± S.D. and constructing diagrams, while analytic approach was used for finding associations by using Chi-square tests and finding p-value, a p-value of ≤ 0.05 was regarded as statistically significant.

4. Results

The mean age was 25.77 years ± 5.91 SD (minimum 16 years and maximum 44 years), 197 patients out of 212 (92.9%) were male while (7.1%) were female and right side was more affected (63.6%) than left side (36.3%).

Football play was the most common mechanism of injury (75.9%), followed by fall events (12.3%), while twist injury

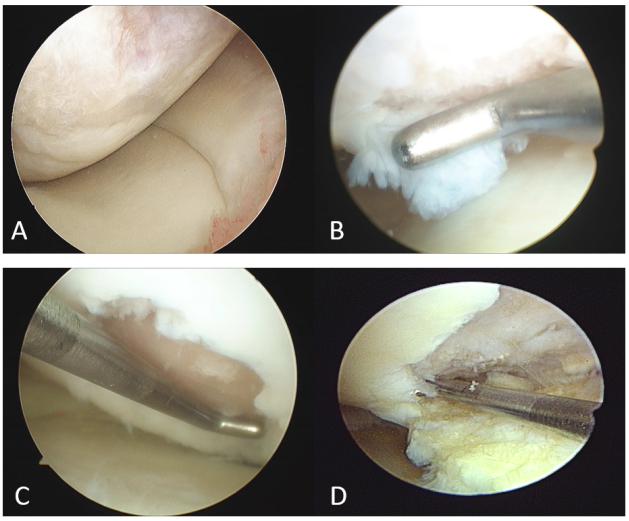

Fig. 5: Arthroscopic images for some of our patients with mild chondral injuries, **A)**: grade 3A "more than 50% loss of cartilage", **B)**: grade 3B "extending till calcified layer", **C)**: grade 3C "extending till subchondral bone", **D)**: grade 4 "extending through subchondral bone" concomitant meniscal injuries were assessed, recorded and treated accordingly

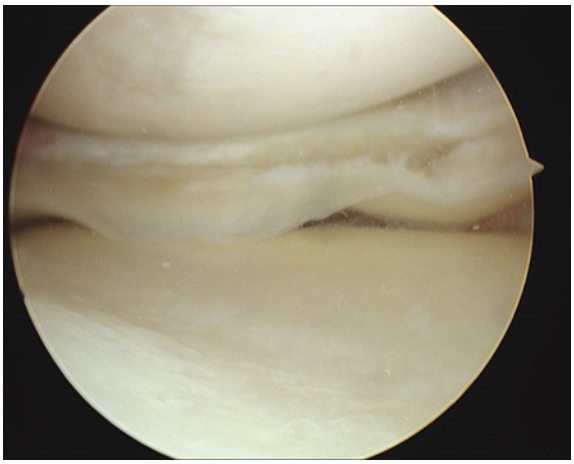

Fig. 6: One of our cases with horizontal meniscal tear

was recorded in (9.9%), sports other than football (1.4%) and one case of motor vehicle accident (0.5%), please see (Table 1).

ACL injury type was studied and correlated with associated chondral damage; partial ACL tear was observed in 7 out of 212 (3.3%) while the majority of cases had complete ACL injury (96.7%), no severe chondral damage was reported in partial ACL tears, please see (Table 2).

Proximal avulsion was the most common pattern (117 out of 205 - 57.1%) among complete ACL ruptures, we could not visualize the ACL in (66 out of 205 - 32.2%) and mid substance rupture was recorded in (22 out of 205 - 10.7%).

Table 1: Results of Gender, Side and Mechanism of Injury

Gender Distribution	
Male	197 (92.9%)
Female	15 (7.1%)
Total	**212 (100%)**
Affected Side	
Right	135 (63.7%)
Left	77 (36.3%)
Total	**212 (100%)**
Mechanism of Injury	
Football Play	161 (75.9%)
Fall Events	26 (12.3%)
Twist Injury	21 (9.9%)
Other Sports	3 (1.4%)
Motor Vehicle Accident	1 (0.5%)
Total	**212 (100%)**

Table 2: ACL injury type correlation with chondral damage

Chondral Damage	**ACL Injury Type**	
	Complete	Partial
Intact (Grade 0)	89 (43.4%)	2 (28.6%)
Mild (Grade 1 & 2)	85 (41.5%)	5 (71.4%)
Severe (Grade 3 & 4)	31 (15.1%)	0
Total	**205**	**7**

Absent ACL showed statistically significant (p-value: <0.001) higher incidence of chondral mild and severe lesions (74.2%) while other two patterns showed no statistically significant correlation with chondral status, please see (Table 3)

Table 3: Compete ACL injury pattern correlation with chondral damage

Chondral Damage	**Complete ACL Injury Type**		
	Proximal Avulsion	Absent	Mid-substance
Intact (Grade 0)	63 (53.8%)	17 (25.8%)	9 (40.9%)
Mild (Grade 1 & 2)	38 (32.5%)	38 (57.6%)	9 (40.9%)
Severe (Grade 3 & 4)	16 (13.7%)	11 (16.6%)	4 (18.2%)
Total	117	66	22

Concomitant meniscal and chondral injuries were reported in 137 cases (64.6%), associated meniscal injury had higher severe chondral damage (20.4%) compared to cases without meniscal injury (4%), please see (Table 4).

Meniscal tears were more frequent on medial 64.9% (89 cases) than lateral 23.4% (32 cases) while tears on both menisci were reported in 11.7% (16 cases), the highest incidence of chondral injuries (mild and severe) were correlated with both meniscal tears (75%) followed by medial (66.3%) and lateral (53.1%) meniscal tears, please see (Table 5).

Table 4: Meniscal status correlation with chondral damage

Chondral Damage	**Meniscal Status**	
	Intact	Tear
Intact (Grade 0)	42 (56%)	49 (35.8%)
Mild (Grade 1 & 2)	30 (40%)	60 (43.8%)
Severe (Grade 3 & 4)	3 (4%)	28 (20.4%)
Total	75	137

Table 5: Meniscal tears correlation with chondral damage

Chondral Damage	**Meniscal Tears**		
	Isolated Medial	**Isolated Lateral**	**Both Menisci**
Intact (Grade 0)	30 (33.7%)	15 (46.9%)	4 (25%)
Mild (Grade 1 & 2)	42 (47.2%)	11 (34.3%)	7 (43.75%)
Severe (Grade 3 & 4)	17 (19.1%)	6 (18.8%)	5 (31.25%)
Total	89	32	16

Complex tear was the most common pattern (30 cases) of medial meniscal tears followed by bucket handle (22 cases) and vertical (17 cases) tears, flap tears was less common but 4 out of 7 flap tears (57.1%) were associated with severe chondral damage with statistical significance (p value: 0.01), please see (Table 6).

Bucket handle tear was the most common pattern (7 cases) of lateral meniscal tears, flap tears was more common (19% of lateral tears) than medial side (7.9%), however; 5 out of 6 flap tears in lateral meniscus were not associated with chondral damage but without statistical significance (p value: 0.3), please see (Table 7).

Chondral injuries were studied over the five articular zones; medial tibia was most commonly affected (54.2%) while patella was the least (28.8%), 4 cases with ICRS grade 4 were observed; all of them were in medial tibia zone, please see (Table 8).

The highest incidence of severe chondral injuries (grade 3 & 4) was observed in medial tibia zone (8%) while no severe chondral injuries were found in patella zone, please see (Table 9).

Medial Tibia zone chondral injuries were increased in rate and severity with time; patients who were operated within 6 months had highest rate of intact cartilage (59.7%) and least frequency of severe chondral injuries (1.5%) while those who operated more than 6 months had higher incidence and more severe chondral injuries over time with statistically significance (p value: 0.014), please see (Tables 10 and 11).

Lateral Tibia zone chondral injuries was increased in rate and severity over time but lesser correlation than medial tibia zone, patients who were operated within 2 years had

Table 6: Medial meniscal tear pattern correlation with chondral damage (p: 0.01)

Medial Meniscal Tear Pattern	Chondral Damage		
	Intact Cartilage	Mild Damage	Severe Damage
Vertical	7 (41.2%)	9 (52.9%)	1 (5.9%)
Flap	1 (14.3%)	2 (28.6%)	4 (57.1%)
Horizontal	3 (75%)	0	1 (25%)
Complex	11 (36.7%)	12 (40%)	7 (23.3%)
Root Avulsion	2 (33.3%)	2 (33.3%)	2 (33.3%)
Radial	0	2 (66.7%)	1 (33.3%)
Bucket Handle	6 (27.3%)	15 (68.2%)	1 (4.5%)
Total	30	42	17

Table 7: Lateral meniscal tear pattern correlation with chondral damage (p: 0.33)

Lateral Meniscal Tear Pattern	Chondral Damage		
	Intact Cartilage	Mild Damage	Severe Damage
Vertical	3 (60%)	2 (40%)	0
Flap	5 (83.3%)	1 (16.7%)	0
Horizontal	3 (50%)	2 (33.3%)	1 (16.7%)
Complex	0	3 (75%)	1 (25%)
Root Avulsion	1 (33.33%)	1 (33.33%)	1 (33.33%)
Bucket Handle	3 (42.8%)	2 (28.6%)	2 (28.6%)
Absent	0	0	1 (100%)
Total	**15**	**11**	**6**

Table 8: Chondral damage grades over the 5 articular zones

ICRS Grade	Chondral Zones				
	MT	LT	MF	LF	P
0	97 (45.8%)	118 (55.7%)	112 (52.8%)	140 (66%)	151 (71.2%)
1A	23 (10.8%)	30 (14.2%)	37 (17.4%)	41 (19.3%)	37 (17.5%)
1B	57 (26.9%)	50 (23.6%)	40 (18.9%)	22 (10.4%)	22 (10.4%)
2	18 (8.5%)	6 (2.8%)	16 (7.5%)	7 (3.3%)	2 (0.9%)
3A	10 (4.7%)	6 (2.8%)	4 (1.9%)	1 (0.5%)	0
3B	2 (0.9%)	2 (0.9%)	1 (0.5%)	1 (0.5%)	0
3C	1 (0.5%)	0	1 (0.5%)	0	0
3D	0	0	1 (0.5%)	0	0
4	4 (1.9%)	0	0	0	0
Total			**212 (100%)**		

Table 9: Chondral damage severity over the 5 articular zones

Chondral Damage	Chondral Zones				
	MT	LT	MF	LF	P
Intact (0)	97 (45.8%)	118 (55.6%)	112 (52.8%)	140 (66.04%)	151 (71.2%)
Mild (1 & 2)	98 (46.2%)	86 (40.6%)	93 (43.9%)	70 (33.02%)	61(28.8%)
Severe (3 & 4)	17 (8%)	8 (3.8%)	7 (3.3%)	2 (0.94%)	0
Total			**212 (100%)**		

least severe chondral injuries (0-2.2%) while those who were operated more than 2 years had higher incidence and more severe chondral injuries with significant p value (0.001), please see (Tables 12 and 13).

On medial femoral side; highest percentage of intact cartilage was observed in patients with less than 6 months duration between injury and reconstruction with no severe chondral injuries recorded in this group while higher rate and more severe chondral injuries were seen with patients operated more than 6 months from injury, furthermore, highest rate of severe chondral injuries were observed in patients who were operated more than 4 years with statistically significance (p value: 0.002), please see (Tables 14 and 15)

Lateral femur zone had less common and milder chondral damage; (79.1%) of patients who were operated within

Table 10: Medial tibia chondral damage grades over time (p: 0.014)

ICRS Grade	Medial Tibia Chondral Damage Grades Over Time					
	<6 months	6-12 months	1-2 years	2-3 years	3-4 years	>4 years
0	40 (59.7%)	23 (51.1%)	12 (48%)	9 (39.1%)	12 (29.3%)	1 (9.1%)
1A	8 (11.9%)	6 (13.3%)	3 (12%)	2 (8.7%)	4 (9.8%)	0
1B	16 (23.9%)	10 (22.2%)	7 (28%)	8 (34.8%)	11 (26.8%)	5 (45.4%)
2	2 (3%)	3 (6.7%)	1 (4%)	2 (8.7%)	8 (19.5%)	2 (18.2%)
3A	1 (1.5%)	2 (4.5%)	1 (4%)	2 (8.7%)	3 (7.3%)	1 (9.1%)
3B	0	0	1 (4%)	0	1 (2.4%)	0
3C	0	1 (2.2%)	0	0	0	0
4	0	0	0	0	2 (4.9%)	2 (18.2%)
Total	(100%)					

Table 11: Medial tibia chondral damage severity over time (p: 0.014)

Chondral Damage	Medial Tibia Chondral Damage Severity Over Time					
	<6 months	6-12 months	1-2 years	2-3 years	3-4 years	>4 years
Intact	40 (59.7%)	23 (51.1%)	12 (48%)	9 (39.1%)	12 (29.3%)	1 (9.1%)
Mild	26 (38.8%)	19 (42.2%)	11 (44%)	12 (52.2%)	23 (56.1%)	7 (63.6%)
Severe	1 (1.5%)	3 (6.7%)	2 (8%)	2 (8.7%)	6 (14.6%)	3 (27.3%)
Total	(100%)					

Table 12: Lateral tibia chondral damage grades over time (p: 0.001)

ICRS Grade	Lateral Tibia Chondral Damage Grades Over Time					
	<6 months	6-12 months	1-2 years	2-3 years	3-4 years	>4 years
0	44 (65.7%)	28 (62.2%)	17 (68%)	11 (47.8%)	16 (39%)	2 (18.2%)
1A	11 (16.4%)	2 (4.45%)	2 (8%)	5 (21.7%)	9 (22%)	1 (9.1%)
1B	11 (16.4%)	12 (26.7%)	5 (20%)	4 (17.3%)	13 (31.7%)	5 (45.4%)
2	0	2 (4.45%)	1 (4%)	1 (4.4%)	2 (4.9%)	0
3A	1 (1.5%)	0	0	1 (4.4%)	1 (2.4%)	3 (27.3%)
3B	0	1 (2.2%)	0	1 (4.4%)	0	0
Total	(100%)					

Table 13: Lateral tibia chondral damage severity over time (p: 0.001)

Chondral Damage	Lateral Tibia Chondral Damage Severity Over Time					
	<6 months	6-12 months	1-2 years	2-3 years	3-4 years	>4 years
Intact	44 (65.7%)	28 (62.2%)	17 (68%)	11 (47.8%)	16 (39%)	2 (18.2%)
Mild	22 (32.8%)	16 (35.6%)	8 (32%)	10 (43.5%)	24 (58.5%)	6 (54.5%)
Severe	1 (1.5%)	1 (2.2%)	0	2 (8.7%)	1 (2.5%)	3 (27.3%)
Total	(100%)					

Table 14: Medial femur chondral damage grades over time (p: 0.002)

ICRS Grade	Medial Femur Chondral Damage Grades Over Time					
	<6 months	6-12 months	1-2 years	2-3 years	3-4 years	>4 years
0	45 (67.2%)	24 (53.35%)	16 (64%)	12 (52.2%)	13 (31.7%)	2 (18.2%)
1A	13 (19.4%)	6 (13.35%)	3 (12%)	3 (13%)	11 (26.9%)	1 (9%)
1B	6 (8.9%)	8 (17.8%)	4 (16%)	5 (21.75%)	14 (34.1%)	3 (27.3%)
2	3 (4.5%)	5 (11.1%)	1 (4%)	2 (8.7%)	2 (4.9%)	3 (27.3%)
3A	0	0	1 (4%)	0	1 (2.4%)	2 (18.2%)
3B	0	0	0	1 (4.35%)	0	0
3C	0	1 (2.2%)	0	0	0	0
3D	0	1 (2.2%)	0	0	0	0
Total	(100%)					

Table 15: Medial femur chondral damage severity over time (p: 0.002)

Chondral Damage	Medial Femur Chondral Damage Severity Over Time					
	<6 months	6-12 months	1-2 years	2-3 years	3-4 years	>4 years
Intact	45 (67.2%)	24 (53.3%)	16 (64%)	12 (52.2%)	13 (31.7%)	2 (18.2%)
Mild	22 (32.8%)	19 (42.2%)	8 (32%)	10 (43.5%)	27 (65.9%)	7 (63.6%)
Severe	0	2 (4.5%)	1 (4%)	1 (4.3%)	1 (2.4%)	2 (18.2%)
Total	(100%)					

6 months had intact cartilage and only two cases of severe chondral damage were observed after 2 years with significant p value (<0.001), please see (Tables 16 and 17)

Regarding patellar zone, no severe chondral injury was observed, mild chondral injuries were highest (72.7%) in patients who were operated after 4 years, however, only 2 cases with grade 2 chondral injury were found in patella; both of them were observed in (less than 6 months) duration group, please see (Tables 18 and 19).

Regardless the articular zone, severe chondral damages were increased from (3%) in (less than 6 months) group to (63.6%) in (more than 4 years) group, please see (Table 20).

5. Discussion

Several studies were investigating the association between the ACL injury-surgery time interval and incidence of secondary meniscal and chondral pathology based on the fact that ACL-deficient knee has rotational instability which may contribute to secondary pathology over time,[17] our study focused on chondral status after ACL rupture with different durations between injury and surgery dates.

Although women have more ligamentous laxity and more liable to injury but our study showed that 197 out of 212 cases (92.9%) with ACL injury were male while 15 (7.1%) were female, other studies also showed male dominance as stated in Razi et al[17] (91.6% male), Sajjadi et al[18] (86.6% male) and Everhart et al[19] (61.4% male), this might be related to sport activity of men specially football which was the most common mechanism of injury in our case series.

The mean age of ACL injury patients in our study was 25.7 years, which is compatible with Everhart et al[19] (26.5 years), Sajjadi et al[18] (28.5 years) and Razi et al.[17] (27.6 years), ACL injury occurs in young people more than older people as young people engage more in sport activities than older people.

Leg dominance was studied by Brophy et al[20] and the findings were supporting that the dominant leg was injured more likely than supporting side, in our study we found that ACL injury was more common on right 63.7% than left side 36.3% which support other studies findings that dominant kicking leg was at higher risk for ACL injury than supporting leg.[20]

In our study 205 out of 212 cases (96.7%) had complete ACL tear while partial tears were reported in (3.3%) only, this supports other studies as Sajjadi et al[18] (93.4% Complete ACL tear), no severe chondral injuries were recorded in partial ACL tears while 31 out of 205 (15.1%) of complete ACL rupture had severe chondral injury.

Regarding complete ACL injury pattern; 117 out of 205 of our cases had proximal avulsion (57.1%) while 22 cases (10.7%) had mid-substance rupture, patients could not recall the exact mechanism of injury whether it was hyperextension or valgus injury, as theoretically proximal tears are more common with hyperextension low-impact injury rather than valgus high-impact injury which may cause mid-substance tear.[21]

ACL was not observed in 66 cases of our cases, only 17 cases of them (25.8%) had intact articular cartilage while 53.8% in proximal avulsion and 40.9% in mid-substance patterns had intact cartilage; absent ACL is associated with higher rate of chondral lesions.

Football was the main mechanism of injury in 75.9% in our study, this is compatible with other studies as Everhart et al[19] (41.3% soccer and football) and Razi et al[17] (45.1% soccer) suggesting higher percentage of ACL injury in non-contact sport due to several biomechanical factors, non-football sport may cause ACL injury but in our society, people are practicing football more than other sports and this reflects why other sports were less frequent (1.4%) than football as a cause of ACL injury in our study.

Regarding chondral injuries, Sajjadi et al[18] showed no significant relationship between injury-surgery time interval and chondral injury, on the other hand; other studies concluded that higher rate of chondral injuries with delaying ACL reconstruction surgery from injury time, Granan et al[22] studied 3475 patients and concluded that cartilage lesion was increased by 1% for each month that elapsed from injury till surgery date, Everhart et al[19] concluded that a delay of even 5 months is associated with higher rate of medial compartment chondral injuries.

Our study findings revealed a significant association between time interval and chondral injury frequency and severity with variable effect on articular cartilage regions, medial tibial zone severe chondral injuries increased from 1.5% in patients operated within 6 months to 6.7% in patients operated in 6-12 months, medial femoral zone showed no severe injuries in patients operated within 6 months while 4.5% in patients operated in 6-12 months, these findings were compatible with Everhart et al[19] results stating increased risk of medial compartment severe chondral injuries (3.11 adjusted odd ratio) in patients

Table 16: Lateral femur chondral damage grades over time (p: <0.001)

ICRS Grade	Lateral Femur Chondral Damage Grades Over Time					
	<6 months	6-12 months	1-2 years	2-3 years	3-4 years	>4 years
0	53 (79.1%)	31 (68.9%)	16 (64%)	15 (65.2%)	22 (53.7%)	3 (27.3%)
1A	7 (10.4%)	7 (15.6%)	7 (28%)	2 (8.7%)	13 (31.7%)	5 (45.4%)
1B	5 (7.5%)	5 (11.1%)	2 (8%)	5 (21.7%)	5 (12.2%)	0
2	2 (3%)	2 (4.4%)	0	0	0	3 (27.3%)
3A	0	0	0	1 (4.4%)	0	0
3B	0	0	0	0	1 (2.4%)	0
Total	(100%)					

Table 17: Lateral femur chondral damage severity over time (p: <0.001)

Chondral Damage	Lateral Femur Chondral Damage Severity Over Time					
	<6 months	6-12 months	1-2 years	2-3 years	3-4 years	>4 years
Intact	53 (79.1%)	31 (68.9%)	16 (64%)	15 (65.2%)	22 (53.7%)	3 (27.3%)
Mild	14 (20.9%)	14 (31.1%)	9 (36%)	7 (30.4%)	18 (43.9%)	8 (72.7%)
Severe	0	0	0	1 (4.4%)	1 (2.4%)	0
Total	(100%)					

Table 18: Patellar chondral damage grades over time (p: 0.001)

ICRS Grade	Patellar Chondral Damage Grades Over Time					
	<6 months	6-12 months	1-2 years	2-3 years	3-4 years	>4 years
0	56 (83.6%)	34 (75.6%)	21 (84%)	16 (69.6%)	21 (51.2%)	3 (27.3%)
1A	4 (6%)	5 (11.1%)	3 (12%)	5 (21.7%)	15 (36.6%)	5 (45.4%)
1B	5 (7.4%)	6 (13.3%)	1 (4%)	2 (8.7%)	5 (12.2%)	3 (27.3%)
2	2 (3%)	0	0	0	0	0
Total	(100%)					

Table 19: Patellar chondral damage severity over time (p: 0.001)

Chondral Damage	Patellar Chondral Damage Severity Over Time					
	<6 months	6-12 months	1-2 years	2-3 years	3-4 years	>4 years
Intact	56 (83.6%)	34 (75.6%)	21 (84%)	16 (69.6%)	21 (51.2%)	3 (27.3%)
Mild	11 (16.4%)	11 (24.4%)	4 (16%)	7 (30.4%)	20 (48.8%)	8 (72.7%)
Severe	0	0	0	0	0	0
Total	(100%)					

Table 20: Chondral damage severity over time regardless articular zone

Chondral Damage	Chondral Damage Severity Over Time					
	<6 months	6-12 months	1-2 years	2-3 years	3-4 years	>4 years
Intact	38 (56.7%)	22 (48.9%)	10 (40%)	9 (39.1%)	11 (26.8%)	1 (9.1%)
Mild	27 (40.3%)	18 (40%)	12 (48%)	8 (34.8%)	22 (53.7%)	3 (27.3%)
Severe	2 (3%)	5 (11.1%)	3 (12%)	6 (26.1%)	8 (19.5%)	7 (63.6%)
Total	(100%)					

operated more 5 months, also Murrell et al[23] showed that patients after 2 years of ACL injury have six-fold more degenerative cartilage loss on medial side than patients examined 2 months after injury.

On lateral side, tibial zone showed increased frequency of severe chondral injury from (0-2.2%) in patients who were operated within (2 years) to 8.7% in patients of (2-3 years) duration group and even higher rate with more prolonged duration groups, femur also showed increased frequency of severe chondral injuries as we did not observe severe chondral injuries in patients who were operated within (2 years) while 4.4% of patients in (2-3 years) duration group had severe chondral injuries, these results suggest that a great influence of rotational instability occurs after 2 years from injury date on lateral side, Everhart et al[19] showed less effect on lateral side with 0.94 adjusted odd ratio of severe chondral injuries on lateral side in patients operated after 5 months.

ACL-deficiency increases tibio-femoral point-loading due to loss of femoral rollback phenomena which constantly

change tibio-femoral contact with motion in normal knee, this may add more load on specific articular surface (which were less loaded before injury).[17]

Patellar region showed no severe chondral injury with all groups; we could not find correlation between severity and injury-surgery time interval, however mild chondral injuries were more frequent with prolonged duration groups, Kladny et al[24] showed that patellar cartilage was thicker (3.72 ± 0.99 mm) compared with other knee articular cartilage regions which may explain why patellar region showed less frequent secondary severe cartilage injury in ACL-deficient knee overtime.

Concomitant meniscal tears were found in 137 out of 212 cases (64.6%), 16 cases with both menisci tears while 89 cases with isolated medial meniscal tear and 32 cases with lateral meniscal tear suggesting the point stress on medial side which was also associated with more severe chondral injuries, patients with concomitant meniscal had higher rate of severe chondral injury (20.4%) than those patients without meniscal tear (4%).

The most common pattern of medial meniscal lesion was complex tear (33.7%), followed by bucket handle tears (24.7%), Christoforakis et al[25] described complex tears as the most common followed by bucket handle, however; we observed (57.1%) of flap tears are associated with severe chondral injuries while (23.3%) of complex tears are associated with severe chondral injuries, Christoforakis et al[25] determined complex and horizontal cleavage tears as risk factors for severe chondral injuries.

The strong points in our study were:

1. Single surgeon (R.M.N.) was assessing and grading the cartilage injuries, inter-observer reliability has influence on results.
2. Different regions of articular cartilage were studied independently showing various effect of ACL-deficiency among cartilage regions.
3. ACL revision cases, concomitant multi-ligament injuries and other factors and pathologies that might have influence of results were excluded.

The weak points in our study were:

1. Our assessment was based on arthroscopic visual grading of cartilage defects alone without correlation with MRI grading as we did not have high-resolution MRI images suitable for grading.
2. Differentiation between acute and chronic cartilage defect was not possible as MRI was not obtained in exact injury date, we did not recognize whether these injuries were due to traumatic event or secondary due to knee rotational instability.
3. Concomitant meniscal injuries were included in this study; this might affect our results as severe meniscal injuries may lead to further cartilage damage, we did not recognize whether our findings were related to meniscal injury or rotational instability of ACL-deficient knee.

6. Conclusion

Delaying ACL reconstruction surgery will increase frequency of chondral injuries, severe chondral injuries rate is increased after 6 months in medial side and after 2 years on lateral side, concomitant meniscal injury is associated with higher rate of severe chondral lesions.

7. Recommendations

We recommend early ACL reconstruction within 6 months of injury to reduce associated chondral and meniscal lesions which may have negative effect on ACL reconstruction outcome and we recommend to take concomitant meniscal tear in consideration as they have association with higher rate of severe chondral injuries.

8. Source of Funding

None.

9. Conflict of Interest

None.

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